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BIOGRAPHIES OF SOME WORMS.

BY A. S. PACKARD, JR.

RETURNING from our journey through the subkingdom of the Mollusca, we will follow the path leading from the Worms up to the Insects. The lowest worms are far more simple in structure than the lowest mollusks. Indeed in organisms like the Vortex, for example, we have forms which serve as a point of departure, ancestral forms, from which the entire animal world above the Infusoria may have been originally derived.

The division of worms is now so vast and unwieldy that it seems impossible to give a general definition of it, and in the present state of science it may be unnecessary. The group embraces all grades of development from simple ciliated forms like the Vortex, Prostomum and Macrostomum, which are scarcely more complicated than the ciliated infusoria, differing chiefly in having genuine cells composing the tissues, up to animals like the earth worms and nereids which are in some respects as high if not higher than the Crustacea and insects.

Claparède in his "Beobachtungen," etc., says that "the Rhabdocœla have interested me on account of their undeniable passage to the ciliated Infusoria. I am truly of Agassiz's opinion that many so-called Infusoria may be simply Turbellarian larvæ; although at first opposed to this opinion I afterwards expressed my views as to the near relationship of the Infusoria as well with the Rhabdocœla as the Dendrocœla. Thus as *Trachelius ovum* forms an evident connecting link between the Infusoria and Dendrocœla, so are the early stages of the Rhabdocœla often scarcely to be distinguished from the Infusoria. In many cases one is in doubt whether he is dealing with a young Turbellarian worm or a ciliate Infusorian." He then describes an Infusorian-like worm in which the mouth opens by a pharynx into a broad body and digestive cavity, with no anal opening. There is thus no digestive cavity separated from the body cavity. There are no other organs except an otolite. This is evidently an immature form, but none the less closely allied structurally to Paramecium and Trachelius.

It should also be remembered that among the worms are many synthetic types which, as regards some organs, remind us of other groups of animals. For example the Rotifers recall the lower Crustacea, and are by some naturalists regarded as such; the Planarians have been considered by Girard, as mollusks, the Polyzoa and Brachiopods are still regarded as mollusks by eminent naturalists, and there are very few who do not place the Tunicates among the latter. On the other hand the Echinoderms are regarded as worms by some, and Amphioxus has been called a worm. Indeed if any one has any prejudices regarding fixed types in nature, and would learn how regardless of preconceived zoological systems the actual state of our knowledge of the lower animals must lead one to become, let him study the animals now placed among the "Worms."

Leaving out of consideration the lowest forms, almost without organs, and many parasitic forms, as a general rule the worms are bilateral, segmented animals with the nervous cords either separate or united by commissures, and resting on the floor of the body under the alimentary canal, which usually (when present) passes directly through the middle of the body. There is in the Annelides a dorsal and ventral blood-vessel, the circulatory apparatus being closed and more highly developed than in the Crustacea and Insects, Limulus excepted. In the lower worms (Platyelminths, Nematelminths, Acanthocephali and Rotatoria) there is a complicated system of excretory tubes, thought by some anatomists to be analogous with the water-vascular system of Radiates.

The organs of locomotion are, when present, simple bristles or prolongations of the walls of the body forming paddle-like flaps.

We are now concerned with tracing the mode of development of some of the typical forms belonging to the different subdivisions, the general relations of which may be seen in the following tabular view, which is taken from Gegenbaur's "Principles of Comparative Anatomy," with the addition of the Brachiopoda, which he still retains among the Mollusca. The Onychophora, represented by Peripatus, are also omitted, as since the publication of Gegenbaur's work, Peripatus has been proved by the researches of Mr. Moseley to be a tracheate Insect.

VERMES.

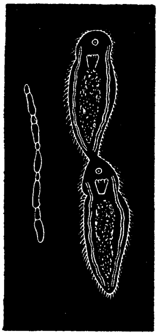
I. PLATYELMINTHES.
  Turbellaria (Vortex, Prostomum, Planaria).
  Trematoda (Distoma, Monostomum).
  Cestoda (Tænia, Bothriocephalus).
  Nemertina (Nemertes).
II. NEMATELMINTHES.
  Nematodes (Strongylus, Ascaris).
  Gordiacea (Gordius, Mermis).
III. CHÆTOGNATHI (Sagitta).
IV. ACANTHOCEPHALI (Echinorhynchus).
V. ROTATORIA (Brachionus, Rotifer).
VI. POLYZOA (Alcyonella, Flustra, Lepralia).
VII. ENTEROPNEUSTI (Balanoglossus).
VIII. TUNICATA (Appendicularia, Ascidia, Pyrosoma, Doliolum, Salpa).
IX. GEPHYREA (Sipunculus).
X. BRACHIOPODA (Lingula, Terebratulina).
XI. ANNULATA (Hirudo, Lumbricus, Nereis, Serpula).

I. PLATYELMINTHES (Flat Worms, Flukes and Tape Worms).

These are flat-bodied ciliated worms without lateral appendages, usually with hooks or suckers. They are usually hermaphroditic.

Development of the Turbellaria. These lowest of worms, in which there is no true stomach and intestines, but a simple short blind digestive sac leading from the mouth and pharynx, are known to multiply by fission, the body dividing into two. They also possess ovaries and male glands, and reproduce from eggs. We are not acquainted with the life-history of the Rhabdocœlous forms, such as Vortex, Prostomum, etc., except that we know that they produce eggs and spermatic particles. In Prostomum, an orbicular form, the yolk cells are formed in a gland (vitellogene) distinct from the true ovary or germ-forming gland (germogene). As an example of reproduction by fission may be cited the singular *Catena quaterna* Schmarda, which occurs in fresh water at the Cape of Good Hope. Fig. 161 represents two individuals in partial division, and a chain of four individuals, natural size. This form reminds us of the tape worm, in

Fig. 161.



Catena quaterna.

which the joints remain permanently attached. We know nothing further regarding the history of Catena except that it has been found as indicated in the figure here reproduced from Schmarda.

Among the Dendrocœla, or Planarians, and in fact in the flat worms generally, fission takes place. If we cut the common fresh water Planarians into several pieces, each piece will become a perfect worm.

All the fresh water flat worms are born as infusorian-like ciliated bodies which attain maturity without any metamorphosis. As an example of the mode of development of a Planarian worm, may be given the history of *Planocera elliptica* discovered by Girard in Boston and Beverly harbors. The spawning time lasts from the middle of May until the middle of June, the eggs being deposited in a thin viscid band on stones and sea weeds. The egg undergoes total segmentation in four or five days after. A ciliated blastoderm begins to form around the yolk mass, and before the embryo leaves the egg it assumes the larval shape, being an infusorian-like form, with a caudal flagellum. There are no internal organs except two eye-specks.

In eight or ten days after the larva begins to revolve in the egg, and after it has hatched, it stops swimming about and becomes a "mummy-like body" which Girard calls a "chrysalis." In this condition, which apparently corresponds to the encysted state of the flukes, it floats about in the water. Here Girard's observations came to an end. Whether in this resting stage it is swallowed by some other animal, and becomes a parasite before resuming its active life, remains to be seen.

The later history of *Planaria angulata* has been traced by Mr. A. Agassiz. "On examining," he says, "a string of eggs, mistaken at first for those of some naked mollusk, I was surprised to find young Planariæ in different stages of growth with a ramifying digestive cavity, somewhat similar to that of adult specimens, but showing besides, one distinct articulation for each spur of the digestive cavity. The eyes were well developed, and when the young became free, the articulations were still distinct." In the youngest specimen (Fig. 162) observed, the body was almost cylindrical, while as seen in Fig. 163, the body has become considerably flattened. The fact that before attaining maturity the Planarian is articulated is very significant, showing that these low worms, non-segmented in maturity, should not be excluded from the class of worms, and that the terms "bilateral, articulate" applies as well to the lowest division (though with many exceptions) of worms as to the true Annelides.

Fig. 162.

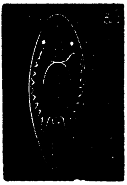
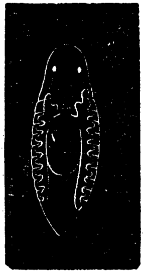


Fig. 163.



Young Planaria.

The Turbellaria then, so far as our limited knowledge extends, develop (*a*) by fission, (*b*) from eggs fertilized by sperm cells, and pass through the following stages, not, however, all observed in a single species.

1. Morula.
2. Infusorian-like stage.
3. A quiet, encysted (?) stage (Girard's Planocera).
4. Articulated stage observed in one species (Agassiz's *Planaria angulata*).
5. Adult, ciliated, not segmented.

Development of the Trematodes. The flukes are parasitic worms, with a sucking disk in the centre of the body by which they attach themselves on or within the body of their host. The fluke or "liver worm" (*Distoma hepaticum*) lives in the liver of the sheep and of man. The fishes and snails are much infested by them, nearly each species having its distinct kind of fluke. The adult flukes are not ciliated, the alimentary canal ends in a blind sac, and the sexes are united in the same individual.

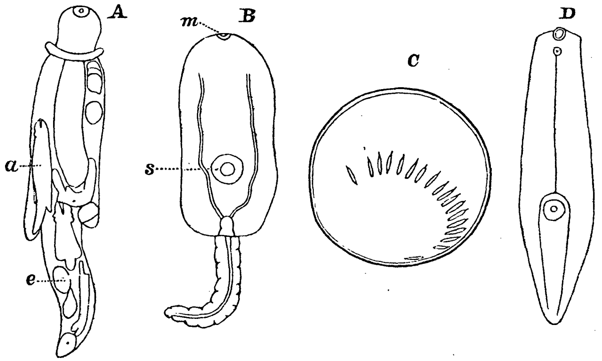
For the mode of formation of the egg of the Trematodes, and the embryonic history of certain forms, the student is referred to Leuckart's "Menschlichen Parasiten" and E. Van Beneden's beautiful "Researches." E. Van Beneden has shown that the development of the Trematodes begins by subdivision of the germinative cellule or nucleus. The nucleus and nucleolus then divide and subsequently the "protoplasmic body." The yolk, however, remains entirely independent of this division, and serves as nourishment for the other cells forming the body of the embryo.

From Van Beneden's observations, it appears that the eggs of the lower flukes as a rule undergo total segmentation, and the young are hatched either oval, ciliated, Infusorian-like, without any organs, not even eye-specks, as in Distoma and Amphistoma; or as in the higher Trematodes, as shown by the elder Van

Beneden, the development is direct, the embryo passing directly into a form like the adult.

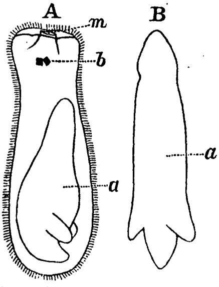
For the further history of the fluke we will turn to Steenstrup's famous work "On the Alternation of Generations," wherein is first related the strange history of these animals. While the flukes were well known, as well as the tadpole-like Cercaria, it was not known before the publication of Steenstrup's work in 1842, that the Cercariæ were the free larval forms of the Distomæ. The *Cercaria echinata*, first described by Siebold, is like a Distoma except that the body is prolonged into a long extensible tail. This tail, says Steenstrup, is formed of several membranes or tubes placed one within the other, of which the outermost is a very transparent epidermis, under which is a tolerably thick membrane furnished with transverse muscular fibres or *striæ*, and between each pair of these transverse fibres is placed a globular vesicle which appears to be a mucous follicle or gland; the innermost tube is opaque and of firmer consistence, it contains the longitudinal muscular fibres, and is usually reticulated on the surface. Through the centre of these tubes there passes a slightly narrower canal, which becomes very small towards the extremity of the tail. The existence of the same layers in the body itself of the Cercaria, can easily be demonstrated; but the transversely striated layer is here not so much developed. This description of the Cercaria will remind one of the tadpole-like larva of the Ascidians. The apparent homology in structure of the tail of the Cercaria with that of the Ascidian larva as figured by Kupffer, is striking. This similarity may be seen if the reader will compare fig. 7, Tab. ii, in De la Valette St. George's "Symbolæ," representing a stage in the development of *Cercaria flava* into *Monostomum flavum*. The author figures a row of cells on each side of a central cavity through which passes what is regarded as possibly a nerve. Whether this is not as much a *chorda dorsalis* and spinal nerve as those parts regarded as such in the Ascidian larva, is a subject for future investigation. But in other respects the position of the mouth, the sense-organs, as well as the form of the body strikingly recall the Ascidian larva, so much so that it gives strong confirmation to the opinion that the Ascidians are worms, and that they and the Trematodes have possibly originated from allied forms. In another species, *Cercaria ocellata*, the tail has a lateral fin; and in still another species figured by J. Müller on the same plate (*Cercaria setifera*) unaccompanied by any description, the tail contains an axial row of large cells, with a row on each side reminding one of the embryo of the Ascidian, with its axial row of cells (the germ of the *chorda dorsalis*) and the cells on each side; moreover the tail is provided with nineteen pencils of long hairs, each pair arising from a distinct segment, so that in one larval Trematode at least, the annulated structure of the body exists, as well as in the larval Planaria.

Fig. 164.



Development of Distoma.

Fig. 165.



Development of Monastomum.

Returning now to Steenstrup's narrative, he tells us that these "Echinate Cercariæ (Fig. 164, A, parent nurse; *e*, germs; *a*, nurse; B, larva), are found by thousands, and frequently by millions in the water, in which two of our largest fresh-water snails, *Panorbis cornea* and *Limnœus stagnalis*, have been kept." After swimming about in the water some time they fix themselves by means of their suckers (B, *s*) to the slimy skin of the snails, in such numbers that the latter look as if covered with bits of wool.

The Cercaria by contracting its body and violent lashing of the tail forces its way into the body of its host, loses its tail, and then resembles a mature Distoma. By turning about in its place and secreting a mucus, a cyst is gradually formed, with a spherical shell. This constitutes the "pupa" state of the Cercaria, first observed by Nitzsch and afterwards by Siebold. Steenstrup thinks that the Cercaria casts a thin skin. In this state the body can be seen through the shell of the cyst, as in Fig. 164, C, where the circle of spines embedded around the mouth is seen.[1] The encysted Cercariæ remain in this state from July and August until the following spring; and during the winter months in snails kept in warm rooms, they change into Distomas (Fig. 164, D) the mature fluke differing, however, in some important respects from the tailless larvæ. In nature they remain from two to nine months in the encysted state.

"Now," asks Steenstrup, "Whence come the Cercariæ?" Bojanus states that he saw this species swarming out from the "king's yellow worms," which are about two lines long and occur in great numbers in the interior of snails. From these are developed the larval Distomas, and Steenstrup calls them the "nurses" of the Cercariæ and Distomata. They exactly resemble the "parent nurses" (Fig. 164, A) and like them the cavity of the body is filled with young, which develop from egg-like balls of cells. Steenstrup was forced to conclude that these nurses originated from the first nurses (Fig. 164) which he therefore calls "parent-nurses." Here the direct observations of Steenstrup on the *Cercaria echinata* came to an end, but he believed that the parent-nurses came from eggs. The link in the cycle of generations he supplied from the observations of Siebold, who saw a Cercaria-like young (Fig. 165, B) expelled from the body of the ciliated larva of *Monostomum mutabile* (Fig. 165, A, *a*, nurse developing from ciliated larva; *m*, mouth; *b*, eye specks). Steenstrup remarks that "the first form of this embryo is not unlike that of the common ciliated progeny of the Trematoda, as they have been known to us in many species for a long time, from the observations of Mehlis, Nordmann and Siebold, and it might at first sight be taken for one of the polygastric infusoria of Ehrenberg, which also move by cilia; whilst in the next form which it assumes the young Monostomum bears an undeniable resemblance to those animals which I have termed 'nurses' and 'parent nurses' in that species of the Trematoda which is developed from the *Cercaria echinata*."

Thus the cycle is completed and the following summary of changes undergone by the lower Distomas present as clear a case of an alternation of generations as seen in the jelly fishes.

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[1] Other figures by Steenstrup and other authors show the form of the encysted Cercaria very distinctly, but in the figure given above only the spines are distinctly represented in the plate from which this is copied.

1. Egg.
2. Morula.
3. Ciliated larva.
4. Cercaria (parent nurse, Proscolex) producing
5. Cercaria (nurse, scolex).
6. Encysted Cercaria (Proglottis).
7. Distoma (Proglottis).

The *Cercaria echinata*, living in snails which are eaten by ducks, have been shown by St. George to develop into the adult Distoma in the body of that bird. It is generally the case that those Distomas which pass through an alternation of generations live in the larval state in animals which serve as food for higher orders. Thus the Bucephalus of the European oyster passes in the encysted state into a fish (Gasterostomum), which serves as food for a larger fish, *Belone vulgaris*, where the cysts of the same worm occur.

Distoma hepaticum, the liver fluke, sometimes occurring in man, is thought by Dr. Willemoes-Suhm to begin its existence as *Cercaria cystophora*, parasitic on a species of Planorbis.

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Leuckart. Die Menschlichen Parasiten. Leipzig. 1868, incomplete.

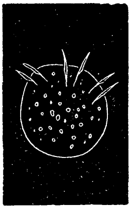
E. Van Beneden. Recherches sur la Composition et la Signification de l'Oeuf. Bruxelles, 1870.

Development of the Cestodes. In the tape worm there is no alimentary canal, the liquid food being absorbed from the juices of its host through the walls of the body. The head is armed with suckers, hooks or leaf-like soft appendages, while the body is subdivided usually into a great number of segments, each containing an ovary and male gland. While the Turbellaria possess a pair of nerve-ganglia, the Cestodes are not known positively to possess any trace of a nervous system.

E. Van Beneden shows that the egg is formed by two glands, one of which (the germogene) forms the nucleus and nucleolus, while the other (vitellogene) forms the yolk. Development begins very probably as in the Trematodes, by multiplication by division of the nucleus (germinative cell). In the eggs of *Tænia bacil-*

laris E. Van Beneden saw the nucleus subdivide; afterwards the cells are arranged in two layers, and the outer layer is thrown off (this probably corresponding to the amnion of insects and crustacea); the central mass forms the embryo, and soon the three pairs of hooks arise as in Fig. 166. Three structureless membranes are secreted around the embryo, which then hatches. The embryo of Bothriocephalus is provided with a ciliated membrane, which corresponds to the first blastodermic moult of the embryo Tænia, which is not ciliated.

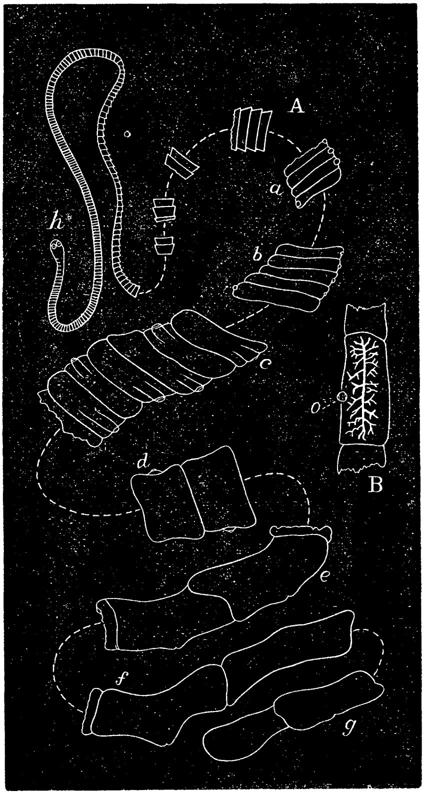
Fig. 166.



Embryo of Tænia.

Now taking up the history of the human tape worm, *Tænia solium* (Fig. 167[1]), the eggs eaten by the hog are developed in its body into the larval tape worm (scolex) called in this species, *Cysticercus cellulosæ*, (Fig. 168; Fig. 169, head enlarged). The head with its suckers is formed, the body becomes flask-shaped (Fig. 168, Cysticercus); the Cysticerci then bury themselves in the liver or the flesh of pork, and are transferred living in uncooked pork to the alimentary canal of man. The body now elongates,

Fig. 167.



Common Human Tape worm.

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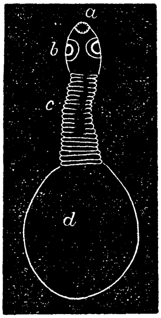
[1] *Tænia solium.* A, the worm natural size; *h*, head; *a*, 309th joint; *b*, 448th; *c*, 569th; *d*, 680th; *e*, 768th; *f*, 849th; *g*, 855th joint and last but one. This worm was 10 feet 9 inches long. B, a separate joint (Proglottis) showing the ovary with its outlet *o*; the same joint contains a testis, too minute to show in the figure. Fig. 168, *Cysticercus cellulosæ*, the larval tape worm, *a*, circle of hooks; *b*, suckers; *c*, wrinkled neck; *d*, sac filled with fluid. This and Fig. 166 and 169 from Weinland.

new joints arise behind the head until the form of the tape worm is attained, as in Fig. 167, after Weinland.

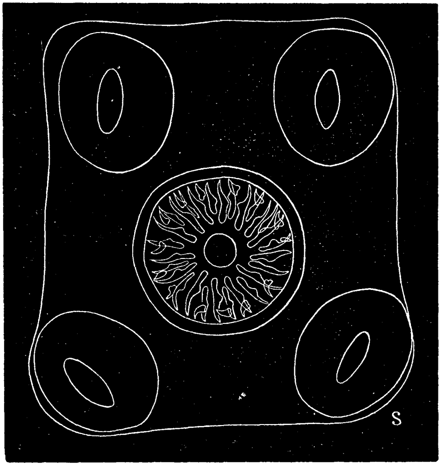
Now we shall see how the eggs are produced. The hinder joints become filled with eggs and then break off, becoming independent animals comparable with the "parent-nurses" of the Cercarias, except that they are not contained in the body of the Tænia (as in the Cercaria), but are set free. The independent joint (Fig. 167, *g*, is called a "proglottis." It escapes from the alimentary tract, and the eggs set free are swallowed by that unclean animal, the pig, and the cycle of generations begins anew. We thus have the following series of changes which may be compared with the homologous series in the flukes:

Fig. 168.



Cysticercus, or larval Tape worm.

Fig. 169.



Head of Cysticercus enlarged, showing the suckers (S) and circle of hooks.

1. Egg.
2. Morula.
3. Double-walled sac (Planula?).
4. Proscolex, free embryo with hooks, surrounded by a blastodermic skin (Amnion?).
5. Scolex (Cysticercus, larva). Body few-jointed.
6. Scolex (Tænia). Body many-jointed.
7. Proglottis (adult).

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P. J. Van Beneden. Les Vers Cestoïdes. Brussels. 1850.

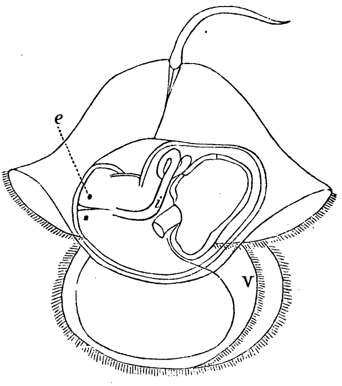
———————. Memoire sur les Vers Intestinaux. Paris. 1858.

Siebold. Ueber die Band- und Blasenwürmer. Leipzig. 1854.
Weinland. An Essay on the Tapeworms of Man. 1858.
Compare also the works of Leuckart, Küchenmeister, E. Van Beneden and Cobbold.

Development of the Nemerteans. In the development of some of these worms we are reminded of the mode of growth of the Echinoderms, while in others the larvæ attain the adult condition by gradual development. In no order of animals, perhaps, is there a greater range of variation in the mode of development than in these curious worms.

The simplest mode of growth is that described by Dieck in Cephalothrix, where the ciliated larva, after passing through a morula and planula[1] stage (being a two-layered sac, but not a gastrula) leaves the egg and undergoes no metamorphosis, the young worm having no body cavity. In the Nemertes larva of Desor there is a body cavity, but the larva is still an infusorian-like being, and attains maturity by direct growth. Another Nemertean (*N. communis*) has been found by Barrois to have a somewhat more complicated mode of growth than in the larva of Desor. The first stages of development are like those of the larva of Desor, the morula passing, as he claims, into a ciliated "gastrula" state in the egg, the body cavity being formed by invagination of the outer layer of cells, but the animal after shedding an amnion leaves the egg in the Nemertes form, and there is no free swimming stage.

Fig. 170.



Pilidium with the Nemertes growing in it.

Now we come to those Nemerteans in which there is a very complicated metamorphosis. J. Müller had described an animal caught with the towing net which he called "Pilidium." Busch had suspected that a Nemertes came from the Pilidium, and Leuckart and Pagenstecker proved it. Our figure taken from the drawings of these two last named authors shows the singular Pilidium, and the planarian-like Nemertes with the eye-specks (Fig. 170, *e*), growing in it. How the worm originates in the body of the Pilidium, and how the latter arises, have lately been fully shown by Metschnikoff, and to his memoir we are indebted for the strange history of the alternation of generations in these worms.

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[1] The inner lining of the planula arises before the body cavity is formed, by a differentiation of a second inner cell-layer, as occurs in other worms, zoophytes, etc. Dieck evidently limits the term gastrula to a two-layered sac, with a body cavity formed by the invagination of the ectoderm Lankester's "gastrula" includes any embryo with a two-layered sac and a primitive cavity. Dieck's planula is like Hæckel's planula of the sponge, the cavity being formed during the segmentation of the egg.

He followed the development of the Pilidium from the egg, which undergoes total segmentation, leaving a segmentation-cavity. The next occurrence is the separation of a one-layered ciliated blastoderm, the ectoderm, which invaginates, forming the primitive digestive cavity, from which the stomach and œsophagus are formed. The larva is now helmet-shaped, ciliated, with a long lash (flagellum) attached to the posterior end of the body.

After swimming about on the surface of the sea awhile, the Nemertes begins to grow out from near the œsophagus of the Pilidium. On each side of the base of the velum (*v*) of the Pilidium appear two thickenings of the skin, one pair in front, the other behind; these thickenings push inwards, and are the germs of the anterior and posterior end of the future worm. The anterior pair become larger than the posterior; the part of the disk next to the œsophagus thickens; at the same time the alimentary canal of the Pilidium grows smaller and only a narrow slit remains. The disks now divide into two layers, the outer much thicker than the inner. A new structure now arises, a pair of vesicles near the hinder pair of disks; these are the "lateral organs" of the future worm. Soon the anterior pair of disks unite and the head of the worm is soon formed, when the elliptical outline of the flat worm is indicated, and appears somewhat as in Fig. 170 (*i*, intestine of the worm). The yolk mass, with the alimentary canal of the Pilidium, is taken bodily into the interior of the Nemertes, the Pilidium skin falls off, and the worm seeks the bottom.

Metschnikoff discovered five other species of Pilidium, and thinks this mode of development is not an uncommon occurrence. This manner of development is directly comparable with that of the echinoderm from the Pluteus.

To show the wide range of metamorphosis existing in the Nemerteans, we may cite the case of a Nareda studied by Mr. A. Agassiz, and whose early stages are like those of the higher Annelides, in fact so much so that Milne-Edwards and Claparède

Fig. 171.

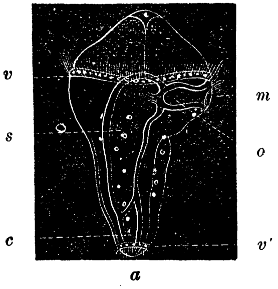


Fig. 172.

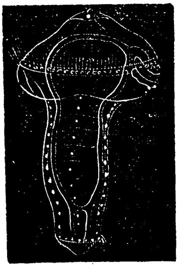


Fig. 173.

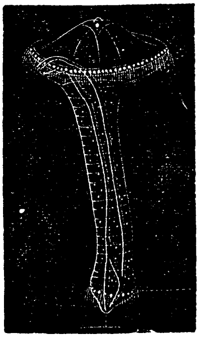


Fig. 174.

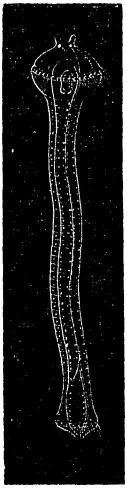


Fig. 175.

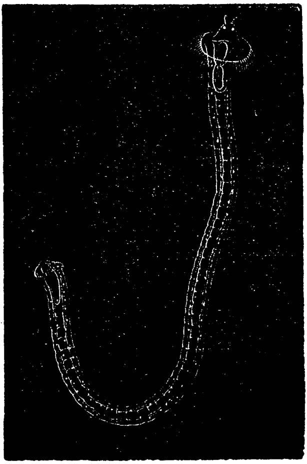
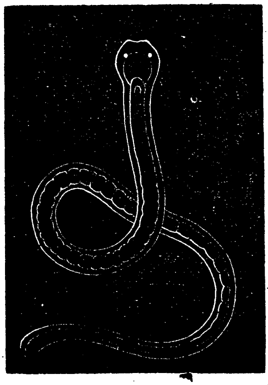


Fig. 176.



Development of a Nemertean worm. After A. Agassiz.

associated "the larva of Lovén" (which Mr. Agassiz has traced without any doubt to the Nemertean worm) with that of Polynoë, a representative of the highest family of Chætopod worms. In the first stage (Fig. 171, *a*, anus; *c*, intestine; *m*, mouth; *o*, œsophagus; *s*, stomach; *e*, eye-speck; *v*, ciliated ring) the larva is not ringed; this figure may be compared with figure 96 on p. 231 to show how much alike the worm and Echinoderm larvæ appear. The new rings are formed between the anal rings and the older anterior rings, as in annelid larvæ, and in fact in the embryos of the Insects and Crustacea. Figs. 172 and 173 represent the ringed larva. "A number of rings make their appearance at once, and are the more distinct the nearer they are placed to the mouth." The worm now greatly elongates, more segments are added and it appears as in Figs. 174 and 175, with the ciliated crown, the small short tentacles and eyes. The worm now swims about slowly and creeps over the bottom, and is nearly a quarter of an inch long. It will be observed that the larva differs from those of other Annelides, as Mr. Agassiz states, in the absence of "feet, bristles or appendages of any sort, except the two tentacles of the head; and, were it not for these, it would seem as if the young worm were the larva of some Nemertes-like animal." Fig. 176 represents the worm over four months after the stage represented by Fig. 175, the articulations have disappeared and a month later the head is separated from the body by a neck, the tentacles disappear, the body is flattened, and the Nemertes (Polia) form is attained.

It is thus interesting to know that the young Echinoderm (Fig. 96), the young mollusk (Fig. 140 B) and the young Nemertean worm pass through a similar free swimming Cephalula stage. We shall see farther on that the young Balanoglossus and the true Annelides pass through a similar phase. The changes through which the Nemertean worms pass are the following, though it should be borne in mind that different species pass through different cycles of growth, some exhibiting no metamorphosis, the stages being more or less condensed in the embryo state.

1. Egg.
2. Morula.
3. Planula (or Gastrula?) hatching as a
4. Ciliated Infusorian-like larva, or a
5. Pilidium or a Cephalula.

.6. Nemertes (*a*) budding out from the Pilidium, or (*b*) arising by direct growth from the Cephalula.

LITERATURE.

Lovén. Jakttagelse ofver Metamorfos hos en Annelid. (K. Vet. Akad. Handlingar. Stockholm, 1840. Translated in Archiv fur Naturgeschichte. 1842, and Annales des Sc. Nat. 1842.)

Desor. Embryologie von Nemertes. (Muller's Archiv, 1848.)

Leuckart and Pagenstecker. Untersuchungen ueber niedere Seethiere. (Muller's Archiv, 1858.)

A. Agassiz. On the young stages of a few Annelides. (Annals Lyceum of Natural History. New York, 1866.)

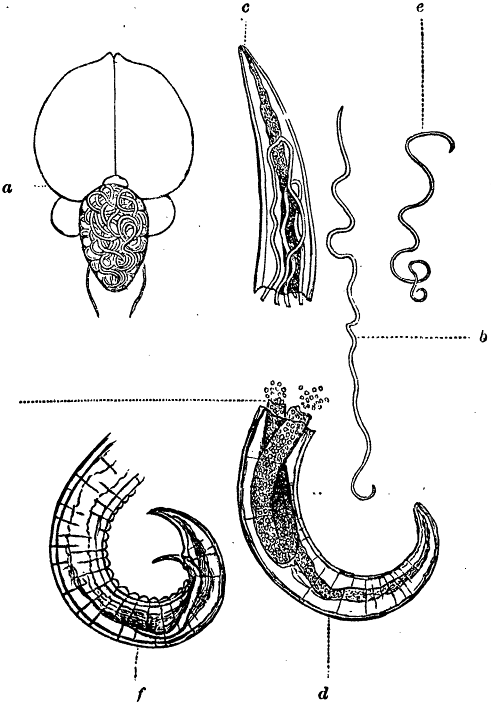
Metschnikoff. Entwickelung der Echinodermen und Nemertinen. (Mémoires Acad. Imp. Sciences. St. Petersbourg, 1869.)

Dieck. Beiträge zur Entwickelungsgeschichte der Nemertinen. (Jenaische Zeitschrift für Naturwissenschaft. 1874.)

II. NEMATELMINTHES (Round worms, Thread worms, Hair worms.)

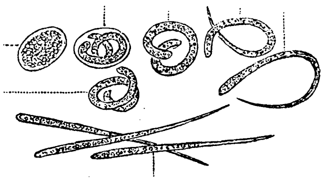
There is little of interest in the development of the ordinary round worms, which whether free or parasitic are of the usual form, as shown in the Eustrongylus.

Fig. 177.



The mode of development of all these worms so far as known is very uniform. Development begins in three ways: (1) usually the egg undergoes total segmentation; others (2), as in *Ascaris dentata* and *Oxyuris ambigua*, do not show any trace of segmentation, and (3) in *Cucullanus elegans* there is no yolk, the nucleus absorbing all the vitelline matter which is limpid and transparent (E. Van Beneden). The germ consists of a single row of cells bent on itself somewhat as in Fig. 178, which represents a little more advanced state in Sagitta, and there are a few cells representing the entoderm. The Nematode may be said therefore to pass through an incomplete gastrula condition. The adult form is rapidly assumed in the egg. Fig. 178 after J. Wyman, represents the young of *Eustrongylus papillosus* in the egg and the worm just after hatching. Fig. 177, *a*, several mature worms coiled up in the brain of the snake bird; *b*, female; *c*, head much enlarged; *d*, end of the body; *e*, male; *f*, the end of its body, after Wyman.)

Fig. 178.



Development of a Round worm.

The *Trichina spiralis* is the author of the terrible disease called trichiniasis or trichinosis. The young worms exist in the flesh of the hog, where they become encysted, and if swallowed by man, the cysts are dissolved during digestion, and the young worms are set free in the intestinal canal. From here the young bore in all directions in the body, and becoming encysted cause the flesh to look as if sprinkled with white sand.

The development of the hair-worm (Gordius and Mermis) is quite complicated, as the young are parasitic, tadpole-shaped, living in the bodies of insects, especially grasshoppers, in whose bodies the mature worms are found coiled up. M. Villot is now publishing an account of the mode of development of these worms in a monograph appearing in Lacaze-Duthiers "Archives, but not yet completed. These worms are oviparous, laying exceedingly numerous, minute eggs agglutinated together, forming long white strings. The young of one genus live in the aquatic larvæ of flies and were afterwards found by Villot in the mucous layer of the intestines of fishes.

The diœcious round worms pass without metamorphosis through a morula, and a condensed gastrula state (not so well marked as in Sagitta) in the egg, assuming the adult form before hatching. In the hair worms there is a well marked metamorphosis.

LITERATURE.

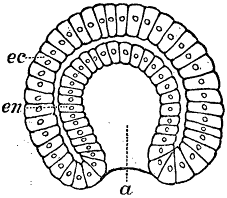
Claparède. De la Formation et de la fécondation des Œufs chez les Vers Nématodes. Genève, 1859. Compare also papers by Bagge, Reichert, Siebold, Nelson, Schneider, Perez, E. Van Beneden and Villot.

III. CHÆTOGNATHI (Sagitta).

This singular worm had been referred to the crustacea by some, to the mollusca by Forbes, and even to the vertebrates by Meissner. Its development and structure, however, show that it is nearly related to the Nematodes. The mouth is, however, armed with six pairs of bristles; and a double-fin-like expansion of the sides and ends of the body gives it a slightly fish-like shape. This fin-like expansion is seen in the Cercaria, and the young ascidian, and is of little morphological importance. It swims on the surface of the water, not seeking the bottom or living parasitically.

Development of Sagitta. This animal is a hermaphrodite, and the eggs may be found in August well developed. Its development has been studied by Gegenbaur and Kowalevsky, by the latter in great detail. The egg undergoes total segmentation, a segmentation cavity being formed and the blastoderm invaginating exactly as in the Nematodes. This results in the formation of a gastrula-condition (Fig. 179) in which the infolding of the blastoderm leaves a well marked primitive body cavity. Soon at the opposite end of the body another cavity (the permanent mouth) forms, which deepens and connects with the primitive body cavity; this closes up at the posterior end, and the true digestive canal is formed. The embryo is oval, but soon elongates, and the adult Sagitta form is attained before the animal leaves the egg.

Fig. 179.



Gastrula of Sagitta.

The phases of development are then as follows:

1. Morula.
2. Gastrula (well marked, but not ciliated and free).
3. Adult Sagitta.

LITERATURE.

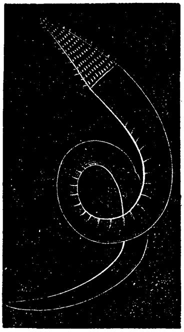
Gegenbaur. Ueber die Entwickelung der Sagitta. Halle, 1857.

Kowalevsky. Embryologische Studien an Würmen und Arthropoden. (Memoirs Acad. Imp. Sciences. St. Petersburg, 1871.)

IV. ACANTHOCEPHALI.

The Echinorhynchus (Fig. 180, head, after Owen); 181, the same, with the proboscis retracted (*a*, oral pore; *bb*, protractile muscles; *cc*, retractile muscles; from Owen), a singular worm, without a mouth or alimentary canal, but with a large proboscis armed with hooks, evidently lives by imbibition of the fluids of its host. It is a not uncommon parasite of fishes. Fig. 182 represents an allied(?) form (*Koleops anguilla*) described by Dr. Lockwood, who found it in the eel (AMERICAN NATURALIST, vi, 1872).

Fig. 182.



Koleops.

Development of Echinorhynchus gigas. Schneider has given the only account we have of the early stages of this worm. "The ova of this worm are scattered upon the ground by the pigs. Here they are eaten by the larvæ of *Melolontha vulgaris* [a beetle allied to our June beetle], and thus arrive at their further development. The ova burst in the stomach of the larva, and the embryos contained in them can then penetrate, by means of their spines, through the intestine into the body cavity of the larva; here they become developed, and again reach the intestine of the pig by the agency of the larva.

Fig. 180.

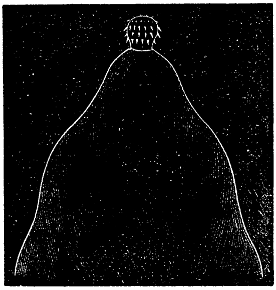
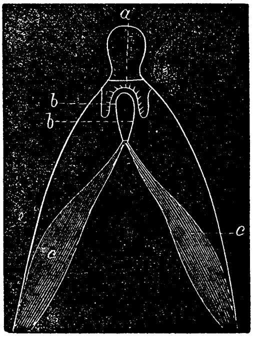


Fig. 181.



Head of Echinorhynchus.

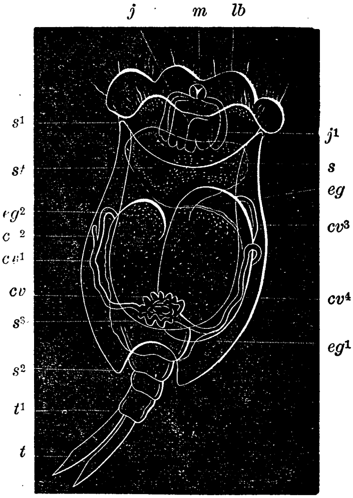
"The larvæ infested with Echinorhynchi live on until their metamorphosis into cockchafers. . . . . When the embryos have arrived at the body cavity of the larvæ of Melolontha, they remain for some days unaltered and capable of motion; they then become rigid, acquire an oval form, and envelope themselves in a finely cellular cyst, which is formed of the connective tissue of the larva. The skin of the embryo, with its circlet of spines at the anterior extremity, continues at first to be the skin of the growing larva; and it is only at a later period, when the formation of the hooks commences, that it is thrown off, when it forms a second cystic envelope. The embryo, or rather the larva, proceeding from it, divides very soon into two layers, a thick dermal layer and an inner cell-mass, from which the other organs originate." The ovaries and testes are produced at a very early stage.

LITERATURE.

Schneider. On the development of *Echinorhynchus gigas*. (Sitzungsbericht der Oberhessischen Gesellschaft für Natur und Heilkunde, 1871. Translated in Annals and Mag. Nat. Hist., 1871.)

V. ROTATORIA.

Fig. 183.



A Rotifer.

The Rotifers, by some eminent naturalists regarded as crustacea, are shelled worms, related to the flat-worms in many respects. The body consists of several segments, and the sexes are very unlike, the small males having the organs more or less rudimental, with no alimentary canal. Like the lower worms they have a set of tubes excretory in their nature and perhaps respiratory, corresponding to the water vascular tubes of the Radiates, but with fine ciliated infundibuliform orifices comparable with the segmental organs of the Brachiopods and higher worms; also a pair of teeth in the pharynx, as in many worms. The anus is situated on the back at the base of the tail. Sometimes the digestive canal ends in a blind sac. The distinctive organ is the retractile, ciliated, paired organ which may be called the velum. Fig. 183[1] from H. J. Clark, represents *Squa-*

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[1] *Squamella oblonga*, magnified 200 diameters. From fresh water. A view from below; shell or carapace (s, s^1, s^2); *s*, the anterior transverse edge of the carapace; s^1, the anterior, and s^2, the posterior corners of the carapace; s^3, the border of the oval, flat area which occupies the lower face of the carapace; *lb*, the cilia-bearing velum of the head; *t*, the fork of the tail (t^1); *m*, the mouth; *j*, jaws; j^1, muscles which move *j*; *st*, stomach; *cv*, the contractile vesicle, or heart of the aquiferous circulatory system; cv^1, cv^2, the right, and cv^3, cv^4, the left aquiferous circulatory vessels; *eg*, eg^1, eg^2, two largely developed young.—Clark's "Mind in Nature."

mella oblonga of Ehrenberg, found in this country. It is closely allied to Brachionus.

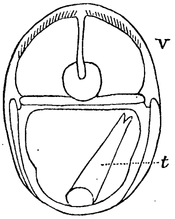
Development of the Rotifers. The sexes are distinct. The females lay both summer and winter eggs, the former being unfertilized, like the summer eggs of the Cladocera (Daphnia). The Rotifers live in damp places in water and revive after being nearly dried up for a long time. Dr. Salensky has been the first to give a complete sketch of the life-history of a Rotifer, *Brachionus urceolaris.*

The eggs of Brachionus are attached by a stalk to the hinder part of the body of the female. The following remarks apply to the female eggs, which are quite distinguishable from the masculine ones. The eggs undergo total segmentation, and the outer layer of cells resulting from subdivision form the blastoderm, when the formation of the organs begins. The first occurrence is an infolding of the blastoderm (ectoderm) forming the primitive mouth, which remains permanently open, the mouth not opening at the opposite end as in Sagitta, but the entire development of the germ is as in Calyptræa, as Salensky often compares the earliest phases of development of the Rotifer with those of that mollusk. The "trochal disk," or velum, as we may call the ciliated disk of the Brachionus, arises as in certain mollusks, as a swelling on each side of the primitive infolding. Behind the primitive hole appears another swelling, which becomes the "foot" or tail.

There is soon formed at the bottom of the primitive infolding a new hole or infolding, which is the true mouth and pharynx, while a swelling just behind the mouth becomes the under lip.

Soon after, the two wings of the velum become well marked, and their relation to the head is as constant as in Calyptræa. The foot becomes conical, larger, and the termination of the intestine and anal opening is formed at the base.

Fig. 184.



Brachionus nearly ready to hatch.

The internal organs are then elaborated; first the nervous system, consisting of but a single pair of ganglia arising from the outer germ-layer (ectoderm). Soon after the sensitive hairs arise on the wings of the velum.

Fig. 184 shows the advanced embryo, with the body divided into segments, the pair of ciliated wings of the velum (*v*), and the long tail (*t*). At this time the shell begins to form, and afterwards covers the whole trunk, but not the head.

The inner organs are developed from the inner germ-layer (endoderm), which divides into three leaves, one forming the middle part of the intestine, and the two others the glands and ovaries. The pharyngeal jaws arise as two small projections on the sides of the primitive cavity.

The male develops in the same mode as the female. The Rotifers, so far as can be judged from one species, seem to develop in a manner quite unlike other worms, and in the earliest phases much as in some Gastropods, the mode of their embryology not throwing much light on the affinities of the group, which is of doubtful position, though with more of the characters of worms than crustacea. The young pass through a morula state, and the embryo directly attains the mature form in the egg.

LITERATURE.

Salensky. Beitrage zur Entwicklungsgeschichte der *Brachionus urceolaris*. (Siebold and Kölliker's Zeitschrift, 1872). Compare also the papers of Huxley, Leydig, Cohn, Gosse and Nägeli.

REVIEWS AND BOOK NOTICES.

SULLIVANT'S ICONES MUSCORUM, OR FIGURES AND DESCRIPTIONS OF MOST OF THOSE MOSSES PECULIAR TO NORTH AMERICA, WHICH HAVE NOT YET BEEN FIGURED.—*Supplement* (*Posthumous*). With eighty-one copper plates, imp. 8vo. Prefaced by a Biographical Sketch of the author, by ASA GRAY. Mr. Sullivant died on the 30th of April, 1873, leaving the plates of this exquisite volume ready for publication, and the letter-press partially so. The latter has been completed by his friend and associate, Mr. Lesquereux; and the volume has at length been brought out, at the expense of Mr. Sullivant's executors, and in accordance with his wishes. Only a very small edition has been printed. The delicate copper plates were not intended for a large impression; and the number of botanists interested in the serious study of mosses is supposed to be small.

As with the larger first volume, with one hundred and twenty-three plates, issued ten years ago, so with this supplementary one now bequeathed to botanists, the sale of the whole edition, at the price for the present fixed, would be far from covering the actual